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COOPERATIVE
RESEARCH

CRASH TEST AND EVALUATION OF A STIFFENED METAL BEAM GUARD FENCE MEDIAN BARRIER FOR USE AROUND LUMINAIRE SUPPORTS

in cooperation with the
Department of Transportation
Federal Highway Administration

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ADAPTATION OF ATTENUATION SYSTEMS

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16. Abstract

A successful full-scale vehicle crash test was conducted on a State Department of Highways and Public Transportation standard Metal Beam Guard Fence (MBGF) median barrier which had been modified to strengthen it in the vicinity of a median mounted luminaire support. Under similar crash tests the standard MBGF would have deflected laterally 1 ft (0.30 m) or more permitting the vehicle to snag or knock down the luminaire pole. The modifications to the median barrier consisted of widening the back to back spacing of the 10 gage "W" sections from 6 in. (15 cm) to 18 in. (46 cm) in a length of 18 ft 9 in. (5.72 m) in order to provide space for the luminaire pole. The 6B8.5 posts were strengthened by increasing the weld metal on the base and by adding additional posts in the transition. The transition was impacted by a 4720 lb (1935 kg) vehicle at an angle of 15 degrees and speed of 61.9 mph (99.6 km/hr). The vehicle was smoothly redirected without snagging or knocking down the luminaire pole. The barrier deflection was nil.

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by

E. L. Marquis
Asst. Research Engineer

T. J. Hirsch
Research Engineer

Research Report 146-13F
Studies of Field Adaptation of Impact Attenuation Systems

Research Study Number 2-10-68-146

Sponsored by
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Texas Transportation Institute
Texas A&M University
College Station, Texas

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

KEY WORDS

Median Barriers, Luminaire Supports, Crash Tests, Highway Safety Guardrails, Traffic Barriers.

FOREWORD

The information contained herein was developed on Research Study 2-5-68-146 entitled "Studies of Field Adaptation of Impact Attenuation Systems." This was a cooperative research study sponsored jointly by the Texas Highway Department and the U.S. Department of Transportation, Federal Highway Administration.

The objective of this study was to evaluate proposed vehicle impact attenuation systems for specific field locations. The most suitable design configuration of the attenuation system was determined through laboratory and full-scale vehicle crash tests. Texas Transportation Institute researchers worked cooperatively with Texas Highway design and field engineers in selecting and designing the appropriate impact attenuation system for various field locations.

Significant findings and development which resulted from this study were documented in the following research reports.

1. "Vehicle Impact Attenuation by Modular Crash Cushion," Hirsch, T. J. and Ivey, Don L., TTI Research Report 146-1, June 1969.

2. "Inservice Experience on Installations of Texas Modular Crash Cushions," White, Monroe C., Ivey, Don L., and Hirsch, T. J., TTI Research Report 146-2, December 1969.

3. "Flexbeam Redirectional System for the Modular Crash Cushion," Hayes, Gordon G., Ivey, Don L., and Hirsch T. J., TTI Research Report 146-3, October 1970.

4. "Vehicle Crash Test and Evaluation of Median Barriers for Texas Highways," Hirsch, T. J., Post, Edward R., and Hayes, Gordon G., TTI Research Report 146-4, September 1972.

5. "Evaluation of Breakaway Light Poles for use in Highway Medians," Walton, N. E., Hirsch, T. J., and Rowan, N. J., TTI Research Report 146-5, May 1972.

6. "Texas Crash Cushion Trailer to Protect Highway Maintenance Vehicles," Marquis, E. L., and Hirsch, T. J., TTI Research Report 146-6, August 1972.

7. "Truck Tests on Texas Concrete Median Barrier," Hirsch, T. J. and Post, E. R., TTI Research Report 146-7, December 1972.

8. "Crash Test of Mile Post Marker," Hirsch, T. J. and Buth, Eugene, TTI Research Report 146-8, January 1972.

9. "Pendulum Tests or Transformer Bases for Luminaire Supports," Buth, Eugene, Hirsch, T. J., Marquis, E. L., and Button, J. W., TTI Research Report 146-9, April 1973.

10. "Chain Link Fence Vehicle Arresting System," Marquis, E. L., Hirsch, T. J., and Hayes G. G., TTI Research Report 146-10, July 1973.

11. "Crash Tests and Evaluation of Single Post Highway Signs," Hirsch T. J., Button, J. W., and Buth, Eugene, TTI Research Report 146-11, August 1973.

12. "Full Scale Tests of a Tire-Sand Inertia Barrier," Marquis E. L., and Hirsch, T. J., TTI Research Report 146-12, February 1975.

13. "Crash Test and Evaluation of a Stiffened Metal Beam Guard Fence Median Barrier for Use Around Luminaire Supports," Marquis, E. L. and Hirsch, T. J., TTI Research Report 146-13F, June 1975.

This is the final research report on this study which terminated on August 31, 1974.

ACKNOWLEDGEMENTS

This study was conducted under a cooperative program between the Texas Transportation Institute and the State Department of Highways and Public Transportation. It was sponsored by the State Department of Highways and Public Transportation and the Federal Highway Administration. Liaison was maintained through Mr. John F. Nixon of the State Department of Highways and Public Transportation and Mr. Edward V. Kristaponis of the Federal Highway Administration. The crash tests and evaluation were carried out by personnel of the Highway Safety Research Center of the Texas Transportation Institute.

ABSTRACT

A successful full-scale vehicle crash test was conducted on a State Department of Highways and Public Transportation standard Metal Beam Guard Fence (MBGF) median barrier which had been modified to strengthen it in the vicinity of a median mounted luminaire support. Under similar crash tests the standard MBGF would have deflected laterally 1 ft (0.30 m) or more permitting the vehicle to snag or knock down the luminaire pole. The modifications to the median barrier consisted of widening the back to back spacing of the 10 gage "W" sections from 6 in. (15 cm) to 18 in. (46 cm) in a length of 18 ft 9 in. (5.72 m) in order to provide space for the luminaire pole. The 6B8.5 posts were strengthened by increasing the weld metal on the base and by adding additional posts in the transition. The transition was impacted by a 4720 lb (1935 kg) vehicle at an angle of 15 degrees and speed of 61.9 mph (99.6 km/hr). The vehicle was smoothly re-directed without snagging or knocking down the luminaire pole. The barrier deflection was nil.

IMPLEMENTATION STATEMENT

It is frequently desirable to use luminaire supports in a highway median in conjunction with a flexible Metal Beam Guard Fence (MBGF) Median Barrier. State Department of Highways and Public Transportation engineers have modified the flexible standard Metal Beam Guard Fence Median Barrier, MBGF(B)-74, to accommodate luminaire supports at discrete locations. The modification consisted of widening the back to back spacing of the 10 gage steel "W" sections from 6 in. (15 cm) to 18 in (46 cm) over a length of 18 ft 9 in. (5.72 m) in order to provide space for the luminaire support. The 6B8.5 posts in the transition length were gradually increased in strength by increasing the amount of weld metal on the base. The last space adjacent to the luminaire is further strengthened by adding an additional post. The luminaire support is between the fourth 6 ft 3 in. (1.9 m) space. Stiffeners are placed between the "W" sections on each side of the luminaire support. The modified design was installed and tested at the Texas Transportation Institute (TTI) Proving grounds.

The transition was impacted by a 4270 lb (1935 kg) vehicle at an angle of 15 degrees with the MBGF centerline at a speed of 61.9 mph (99.6 km/hr). The modified median barrier behaved as intended by smoothly redirecting the vehicle without snagging or knocking down the luminaire pole. The median barrier lateral deflection was nil. Under similar test conditions the standard MBGF median barrier would have deflected laterally 1 ft (0.30 m) or more permitting the vehicle to snag or knock down the luminaire pole.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

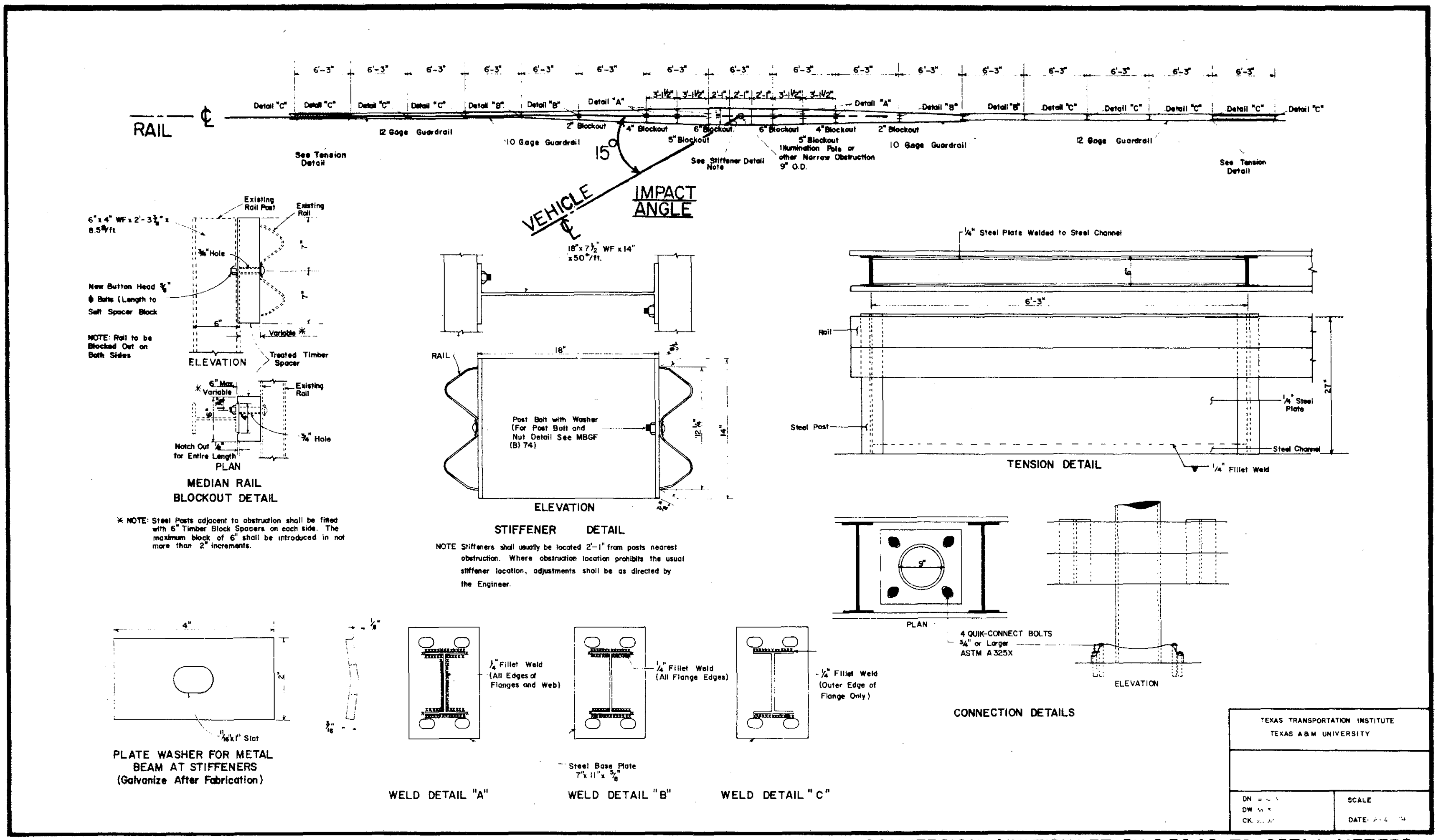
The State Department Highways and Public Transportation utilizes, in most cases, two basic median barrier designs to prevent median cross over accidents. These are the Concrete Median Barrier (CMB) and the Metal Beam Guard Fence (MBGF). The concrete median barrier is an unyielding or rigid barrier and the metal beam guard fence is a flexible barrier that deforms laterally on vehicle impact.

Previous crash tests conducted by Post et al. (2) and Ross (4) have indicated that the flexible metal beam guard fence median barrier will deflect laterally up to 1.0 ft (0.30 m) during vehicle impacts. It was concluded that it would not be desirable to install median mounted luminaire supports in conjunction with this flexible barrier since the vehicle could potentially snag or knock down the luminaire pole during impact. Since it is frequently desirable to have luminaire supports in a median protected with the metal beam guard fence, a safe design for such an installation was desired. State Department of Highways and Public Transportation engineers reviewed several proposed designs prepared both in house and by TTI. The design described herein appeared to meet the desired stiffness requirements and was selected for full-scale testing.

Description of the Metal Beam Guard Fence Tested

The standard metal beam guard fence (SDHPT designation MBGF(B)-74) is designed using the "weak post" concept. On impact the 6B8.5 support post breaks away from its base, allowing the back-to-back guardrail to deflect laterally. The 3/8 in. (.95 cm) fillet welds connecting the two outer faces of the post flanges to the 5/8 in. (1.6 cm) base plate are designed to fracture at relatively low impact forces. Since the posts shear off at the base, there is a reduced tendency for the deflecting rail to rotate downward, thus minimizing the possibility of vehicle ramping.

The standard metal beam guard fence was modified by widening and strengthening a discrete length of the fence to allow a luminaire support to be placed between the side rails as shown in Figure 1. The primary features of the modification were to increase the space between the 10 gage steel rails to 18 in. (46 cm) at the luminaire support by the addition of 18 in. (46 cm) spacers on each side of the luminaire support; the addition of one additional post in the spaces adjacent to each side of the support; and the gradual increase in strength of the shear connection between the post and base plate. The transition from a 6 in. (15 cm) to the 18 in (46 cm) spacing between rails was over three post spaces or 18 ft 9 in. (5.72 m). During construction particular attention was given to the direction of lap of the rails for each of the 25 ft (7.62 m) lengths. The lap was made so that the vehicle would not snag if it were intercepted. The rail sections in the vicinity of the test were rolled from 10 gage galvanized steel stock. These modifications transformed the flexible metal beam guard fence to a "Strong beam Strong post" type in the vicinity of the luminaire support. Figure 2 shows pictures of the guard fence and modification before the test. The A-frame and boom was used to support the overhead camera.



CONVERSION MULTIPLY FT. BY 0.3048 TO OBTAIN METERS

FIGURE 1 PLAN AND DETAILS OF TEST BARRIER

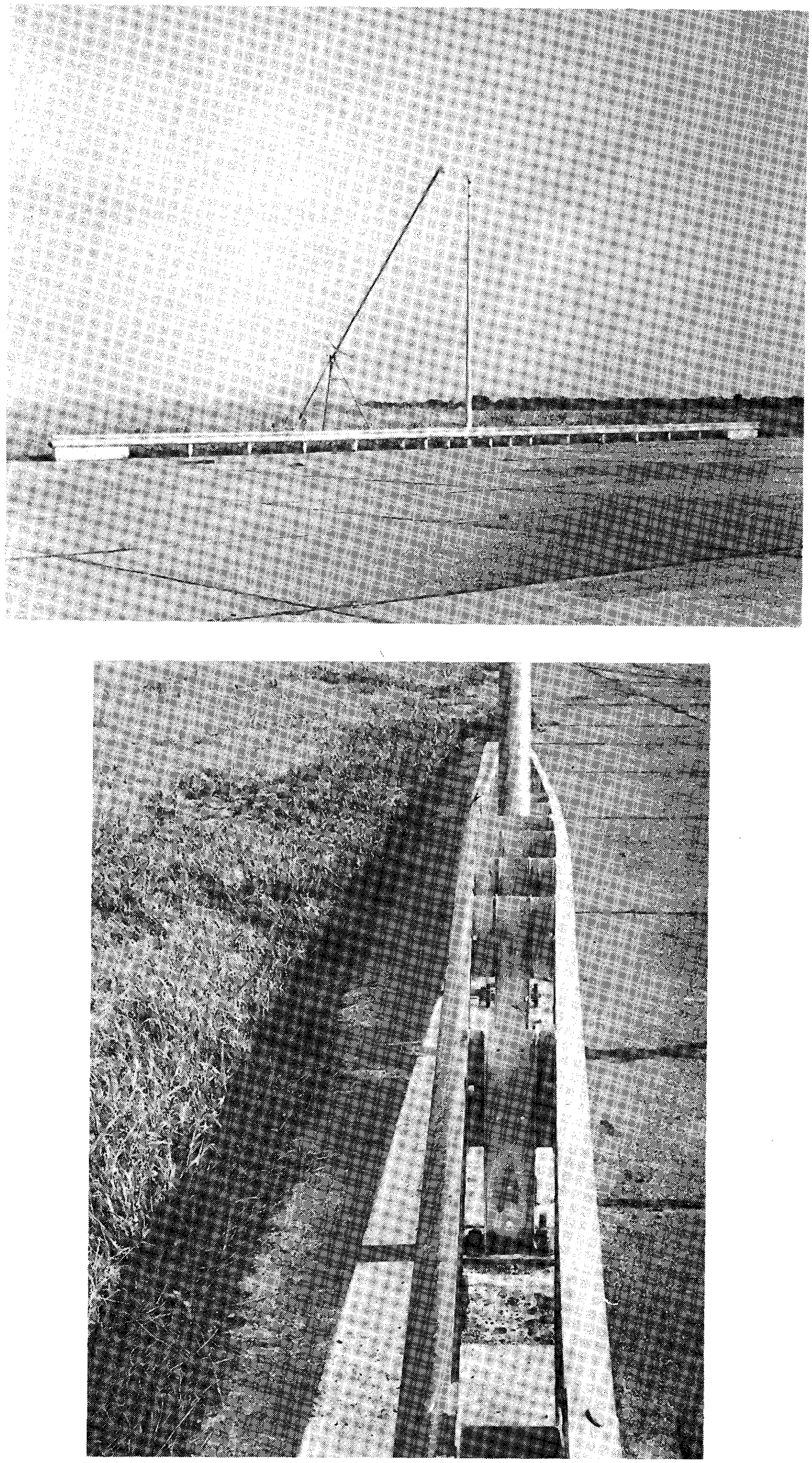


FIGURE 2 TEST MB101 MEDIAN BARRIER
BEFORE IMPACT

VEHICLE AND INSTRUMENTATION

The vehicle used in the full-scale test was a 1963 Mercury Monterrey 4-door Sedan shown in the top photo of Figure 3. The test weight of 4270 lb (1935 kg) included the anthropometric dummy which was secured in the driver's seat with a lap belt anchored through a load cell which indicated lap belt force.

Londitudinal and lateral accelerometers were mounted on each longitudinal frame member to sense vehicle accelerations. A flash bulb and an event mark on the electronic data were actuated by a tape-switch on the front bumper. This allows the electronic data to be synchronized with the high speed film. All electronic data were transmitted by telemetry to a ground station where the data were recorded on magnetic tape and displayed in analog form on a strip-chart.

In addition to documentary motion pictures, the tests were recorded on high-speed films which include timing marks. This film was analyzed to give time displacement data for the vehicle. One data camera was oriented perpendicular to the test metal beam guard fence; one data camera was oriented parallel to the test barrier; and the third was mounted directly above the impact point. The sequential photographs in the "Description of Tests" section were made from high-speed motion pictures from the overhead camera and the camera parallel to the test barrier.

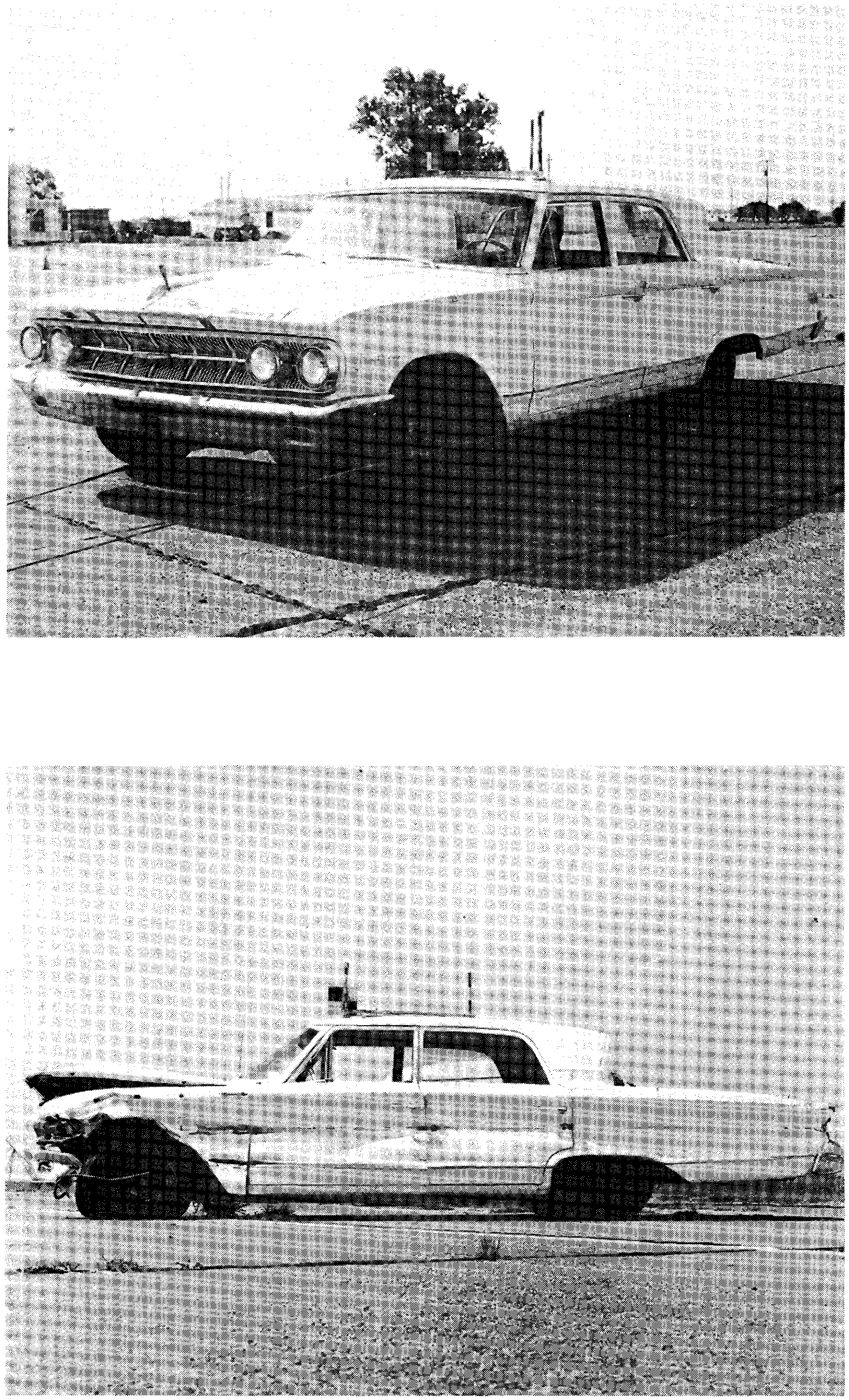


FIGURE 3 TEST MB101 VEHICLE BEFORE AND AFTER IMPACT

CRASH TEST RESULTS

The test, designated as MB-101, was conducted with a 1963 Mercury Monterrey 4-door Sedan weighing 4270 lb (1935 kg). The impact angle of the test vehicle and the metal beam guard fence was 15^{o} as measured between the vehicle centerline and the guard fence centerline. The point of impact of the left front fender of the vehicle and guard fence was approximately 9 ft 8 in. (3.35 m) upstream from the luminaire support. This impact point was determined by guiding the center of gravity of the vehicle directly at the luminaire support (see Figure 1) in order to obtain maximum vehicle penetration at the pole location. The impact speed was 61.9 mph (99.6 km/hr). The vehicle exit angle was approximately 10 degrees and it was smoothly redirected without snagging the luminaire pole. The left front wheel and steering linkage were damaged, see the lower part of Figure 2 and the vehicle was inoperable after impact.

The median barrier is shown after the impact in Figure 4. The "W" section is deformed in the vicinity of the impact and the impacted post and the intermediate post are slightly bent about their bases. The spacer on the intermediate post is damaged. Repair to the metal beam guard fence, if required at all, would be limited to the replacement of one length of "W" section and two posts with spacers.

The vehicle path is shown plotted to scale in Figure 5. The path shown is for the left front wheel. Sequence photographs shown in Figures 6 and 7 show that the vehicle fenders deform and go over the impacted "W" section. It appears that at time 174 milliseconds the sheet metal contacted the luminaire support. A study of the accelerometer traces shows that this contact had little effect on the behavior of the vehicle, and is therefore considered to be insignificant or not a snag. The highest 50 millisecond average longitudinal deceleration occurred at about 70 msec. and was 2.7 G's. (Accelerometer traces are presented in the Appendix.) The highest 50 millisecond average lateral acceleration was 6.5 G's. The vehicle did not exhibit any tendency to roll.

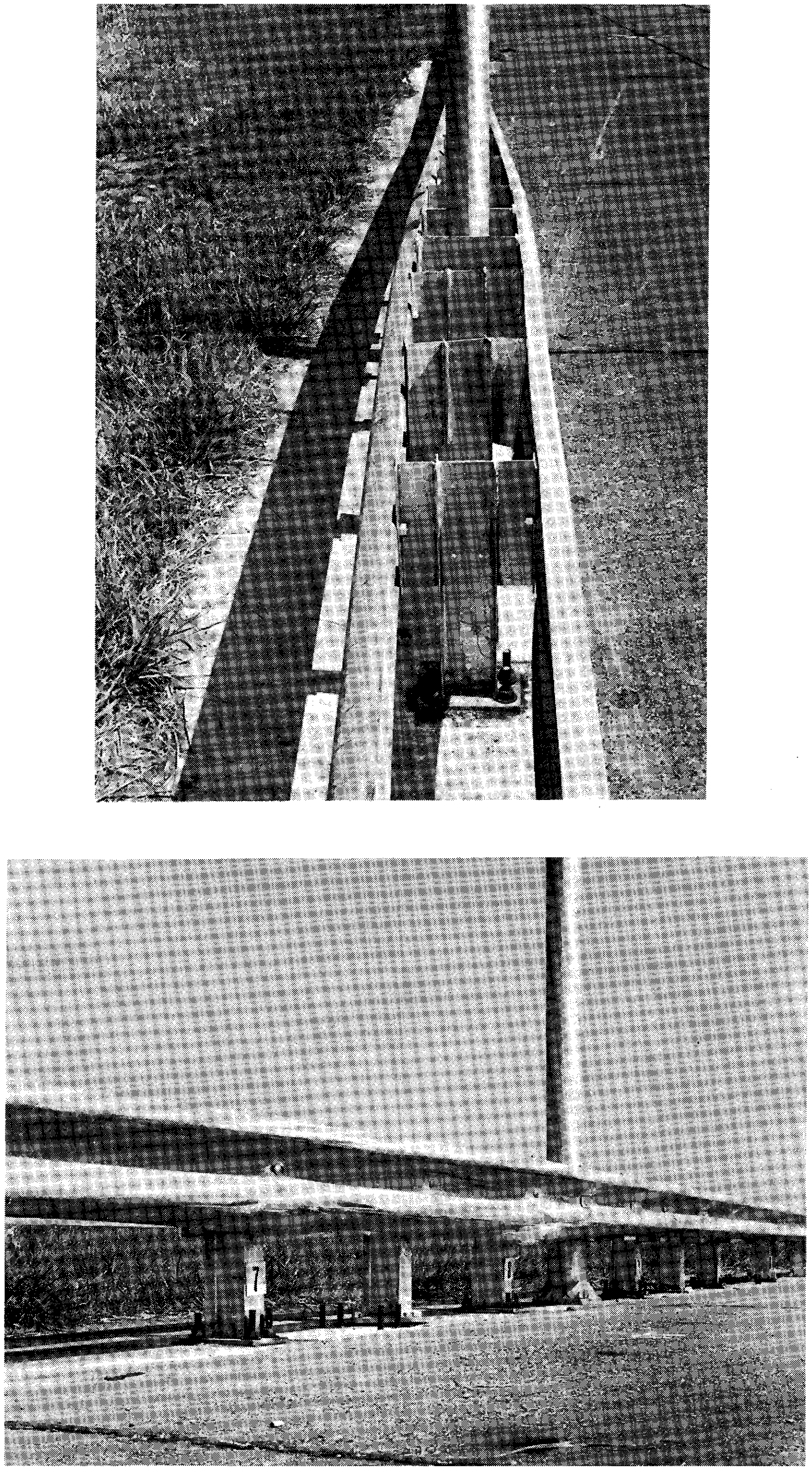


FIGURE 4 TEST MB101 MEDIAN BARRIER
AFTER IMPACT

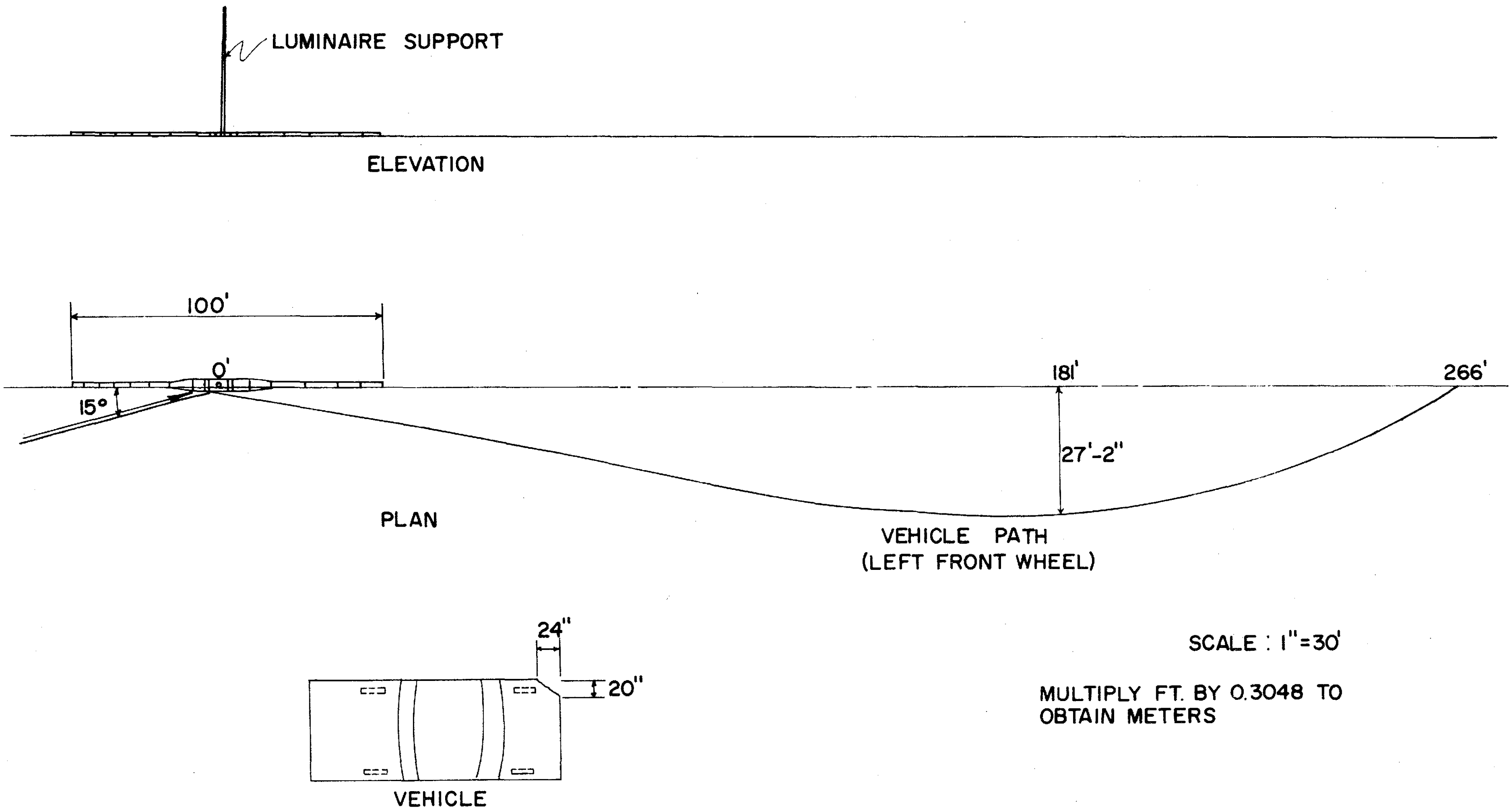


FIGURE 5 TEST MB101 VEHICLE PATH AFTER TEST

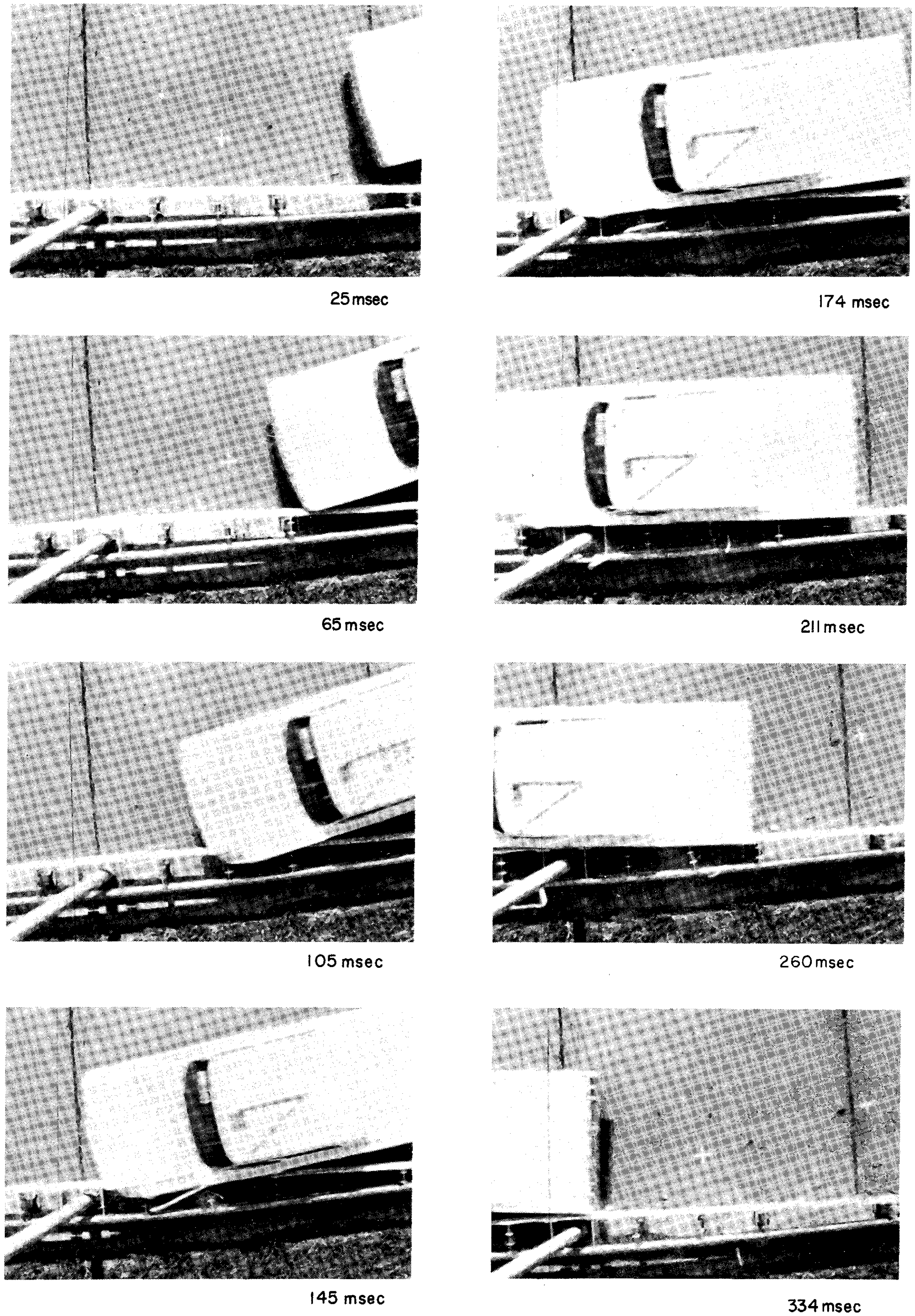


FIGURE 6 TEST MB101 OVERHEAD SEQUENCE PHOTOGRAPHS

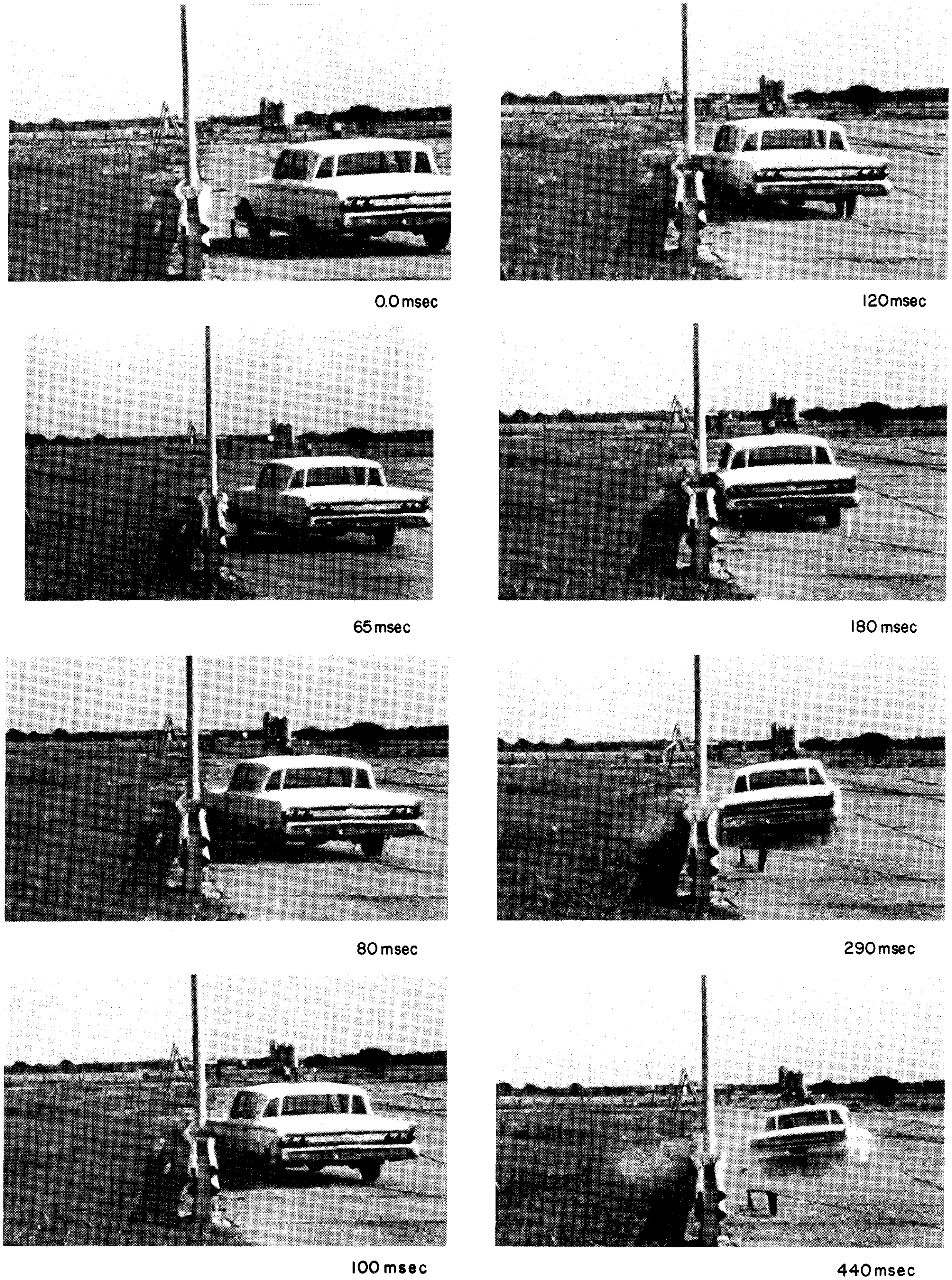


FIGURE 7 TEST MB101 SEQUENCE PHOTOGRAPHS

DISCUSSION OF RESULTS

The Standards of the State Department of Highways and Public Transportation (5) on page 4-94 of the "Operations and Procedures Manual" states that the metal beam guard fence shall be used for medians 20 to 30 ft (7.3 to 9.1 m) in width and either the metal beam guard fence or concrete median barrier may be used for medians 18 to 24 ft (5.5 to 7.3 m) in width. According to the results presented by Ross (4) the maximum angle which would be achieved by 80 percent of the vehicles from the inside traffic lane to the median barrier in a 30 ft (9.1 m) median would be approximately 15°. For medians less than 30 ft (9.1 m) the 15 degrees would be conservative.

Table 1 presents a summary of the test results. The modified MBGF imposed peak decelerations on the vehicle of 4.25 G's longitudinal and 13.9 G's lateral. The highest 50 msec average longitudinal deceleration was 2.7 G's while the 50 msec average lateral deceleration was 6.5 G's. This 6.5 G's average lateral acceleration is in excess of the 5.0 G value suggested by NCHRP Report 153, "Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances" (8), however, it is well within the 9 G value suggested for occupants with lap belt restraint and well below the 15 G's for occupants with lap belt and shoulder harness restraint suggested in NCHRP Report 158 (9).

The 5 G maximum 50 msec average lateral acceleration suggested by NCHRP Report 153 needs re-evaluation in the opinion of these researchers, since it is believed that few, if any, of the existing rigid longitudinal traffic rails will meet this criteria.

TABLE 1

SUMMARY OF TEST RESULTS

	TEST 2146 MB-101
Vehicle:	
Make:	
Style:	Mercury 4-door, Sedan
Year:	1963
Weight lb	4270
kg	1935
Dummy Weight lb	165
kg	75
Impact speed, fps	90.7
mph	61.9
km/hr	99.6
Impact Angle: degrees	15
Exit Angle: degrees	10
Barrier Deflection, lateral, ft	nil
Accelerometer Data:	
Longitudinal[1]	
Peak (G's)	4.25
Highest Average (G's)[2]	2.7
Lateral[1]	
Peak (G's)	13.9
Highest Average (G's)[2]	6.5
Severity Index	1.36
Seat belt peak load lb	100
kg	45

[1] With respect to vehicle fixed axis

[2] Averaged over 50 milliseconds

CONCLUSIONS

The modifications designed to strengthen the State Department of Highways and Public Transportation standard Metal Beam Guard Fence median barrier, MBGF (B)-74, in the vicinity of a luminaire support behaved as intended by smoothly redirecting a 4270 lb vehicle impacting at 15 degrees without snagging on the luminaire pole. Damage to the vehicle and barrier were moderate.

The left front wheel and steering linkage were damaged so the vehicle was inoperable after the impact. Repairs to the metal beam guard fence, if required at all, would have been limited to the replacement of one length of 10 gage "W" section and two posts with spacers.

The highest 50 msec average longitudinal deceleration was 2.7 G's and the 50 msec average transverse acceleration on the vehicle was 6.5 G's. The 6.5 G, 50 msec, average transverse acceleration exceeds the 5 G maximum suggested by NCHRP Report 153. It is the opinion of the researchers, however, that the 5 G maximum value needs re-evaluation since it is believed that few, if any, of the existing rigid longitudinal rails will meet this criteria. Also, the expected frequency of impact angles less than 15° and the acceptable acceleration of 9 G's (9) for occupants with lap restraint only, it is suggested that the 5 G maximum lateral acceleration criteria is overly restrictive and that the 6.5 G's measured in this test is reasonable and appropriate.

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6. Olson, Robert M., Post, Edward R., and McFarland, William F., "Tentative Service Requirements for Bridge Rail Systems," NCHRP Report 86, 1970.

7. Weaver, Graeme, D., Marquis, Eugene, L. and Olson, Robert M., "Selection of Safe Roadside Cross Sections," NCHRP Research Results Digest, Digest No. 71, May 1975.

8. Bronstad, M.E., and Michie, J.D., "Recommended Procedures for Vehicle Crash Testing of Highway Structures," NCHRP Report 153, 1974.

9. Weaver, Graeme D., Marquis, Eugene L., and Olson, Robert M., "Selection of Safe Roadside Cross-Section", NCHRP Report 158, 1975.

APPENDIX

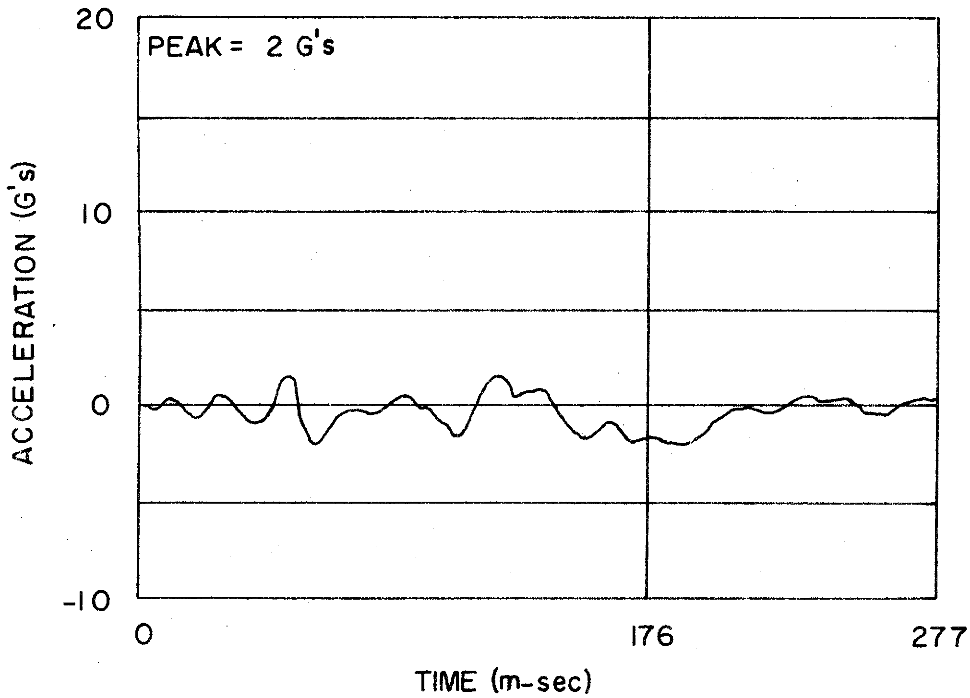
TABLE A-1

TABLE OF EVENTS

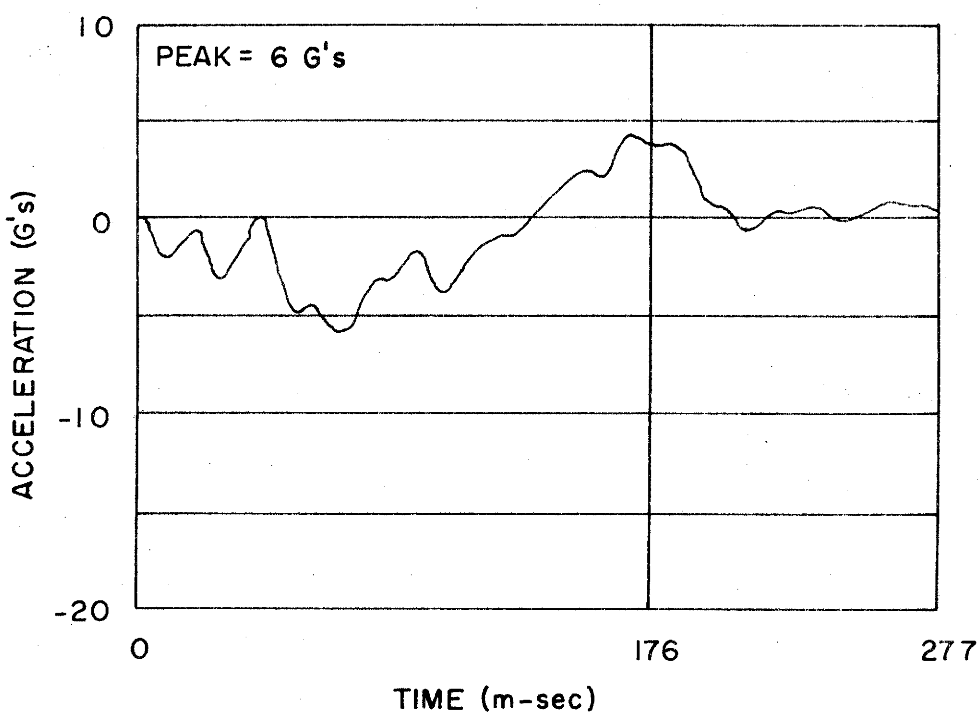
TEST 2146 MB-101

TIME (sec)		EVENT
0.000	-	Flash first starts to go off.
0.065	-	*IMPACT* - of the front left bumper and the guardrail.
0.110	-	Front left fender crumbling.
0.170	-	Left front door appears to be opening.
0.176	-	Front fender scraping the pole.
0.225	-	Front tires parallel to pole and the entire car is parallel to the guardrail, rt- rear up - 1°.
0.240	-	Rear end of car is moving into the guardrail, rt- rear up - 1°.
0.250	-	Right side of car is lifting up.
0.254	-	Front end beginning to move right, away from the rail.
0.297	-	Center of gravity is parallel to the pole, rt- rear up - 3°.
0.440	-	Right rear end is still up in the air, rt - rear up - 4.25°.
2.090	-	Front end beginning to turn to the left.
4.380	-	Front fender once again is in line with the pole while at an angle to the barrier at 260' beyond the pole.
4.800	-	Trunk latch is in line with the pole.
5.000	-	Car is off the pavement.

END OF TEST

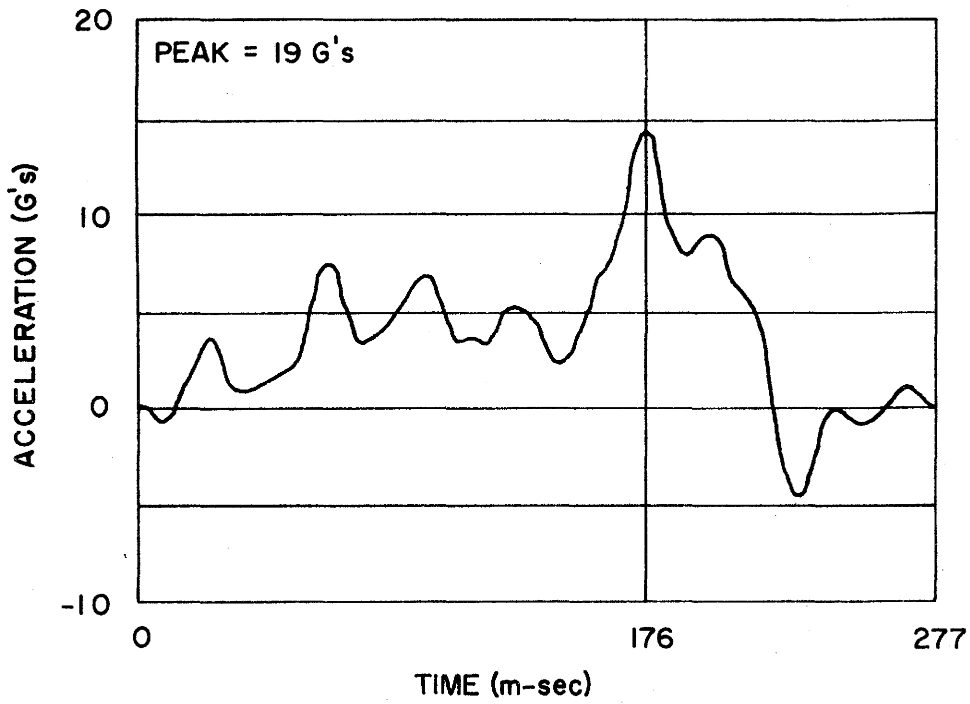


LEFT LONGITUDINAL

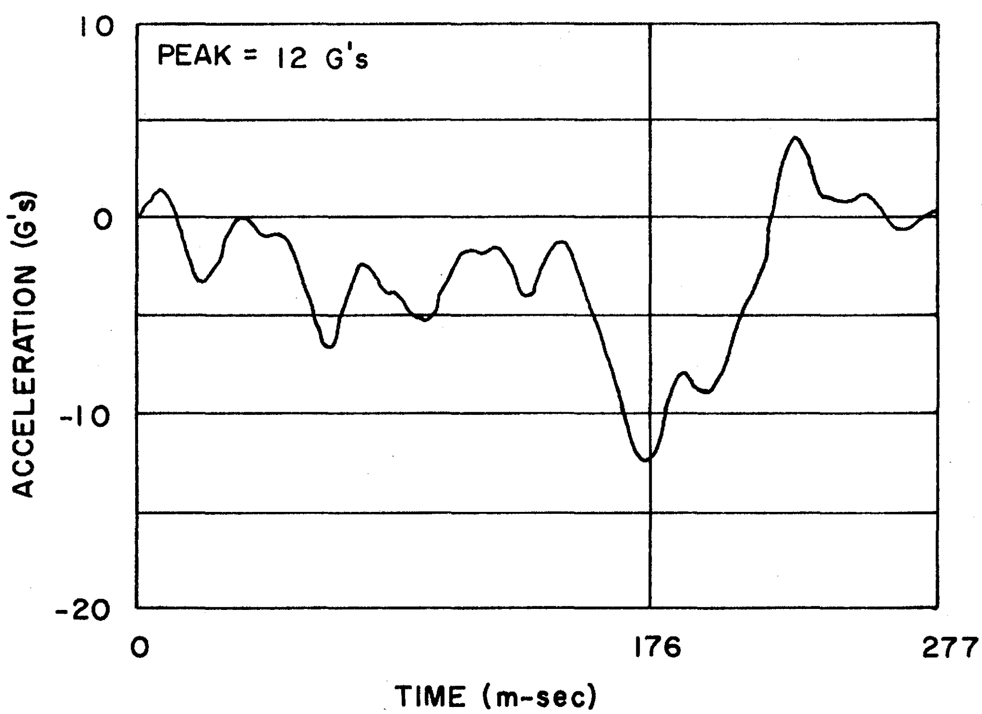


RIGHT LONGITUDINAL

FIGURE **A-1** TEST MB101 LONGITUDINAL ACCELEROMETER DATA



LEFT TRANSVERSE



RIGHT TRANSVERSE

FIGURE **A-2** TEST MB101 TRANSVERSE ACCELEROMETER DATA

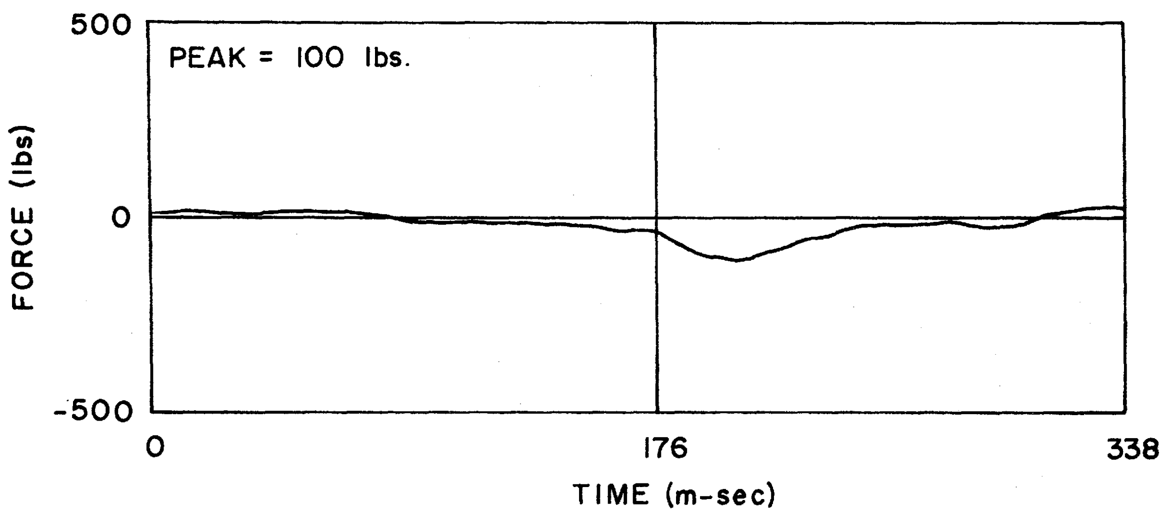


FIGURE A-3 TEST MB101 SEAT BELT FORCE DATA